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Machine Learning-Based System for Hotspot Detection and Analysis

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Abstract: In electrical equipment excessive temperature leads to failures, therefore thermal monitoring plays a major role. For preventing equipment failures, thermal imaging cameras are routinely used for monitoring the condition of electrical equipment. Initial cost for installing thermal imaging cameras is very expensive. This paper introduces the extraction of thermal images from a low-cost web camera. The webcam modified in such a way that IR filter is removed, and a color filter is introduced to get more precise thermal image data. Captured image is in black and white format. Temperature is measured manually, and a software introduced to compute corresponding the RGB values. Regression technology based on Artificial Neural Network (ANN) is used to predict the exact temperature of the corresponding thermal image. A PC speaker is utilized to announce the predicted output in audio format.

Keywords: Thermal Image, Color Filtering, Regression, Artificial Neural Network, Convolutional Neural Network.

1. INTRODUCTION

The majority of electrical equipment failures are caused by an increase in temperature[1]. As a result, thermal monitoring is always important for detecting incipient defects. For monitoring and problem diagnosis, a cost-effective, reliable, and non-contact type infrared thermographic inspection system is now commonly used [2]. Thermal images of some electrical equipment were captured and transformed to the HSI color model for further analysis [3].

Condition Monitoring (CM) [4] has become a very important technology in the field of electrical equipment maintenance Increasing interest has been seen in the field mainly including transformer [5], generator and induction motor in a power plant as because of reduced operating cost, enhanced consistency of operation, improved power supply and superior service to customers [6]. Therefore, intensive care is being required for fault detection of electrical equipment. For electrical equipment monitoring and problem diagnosis, Infrared Thermography (IRT) [7] has been frequently employed. A comparison of the hot spot temperature and the reference temperature is used to assess the condition of electrical equipment [8]. Infrared thermographic inspection systems that are cost effective, dependable, and non-contact are now frequently used for monitoring and fault diagnosis[9]. The use of an infrared thermography is critical in the monitoring of electrical equipment, however due to limitations in thermograph technology and interference from the environment, Image Thresholding based on fuzzy can be used instead [10-12].

The goal is to create a thermal camera out of a standard web camera. The cost of the device will be maintained as low as feasible [13]. With the help of PC-based software, the device is expected to identify various objects and color patterns via image processing [14]. The PC run software is then supposed to produce an audio output of the recognized image/pattern using its speakers. In the decision-making process, we propose to use artificial intelligence [15] and prefer regression techniques for video processing. From various topologies like Artificial Neural Network (ANN) [8], Convolutional Neural Network (CNN) [16] etc. regression is selected due to its lightweight performance over live video processing. We intend to apply a variety of regression approaches in order to determine the best appropriate techniques for the current project.

2. LITERATURE REVIEW

Infrared thermography is one of the latest diagnostic technologies that is becoming popular as it has shown high effectiveness in evaluating power equipment and IRT techniques serve to minimize the downtime and improve the maintenance measures as well as operational reliability of equipment. For example, Sorensen et al. suggested integrating adaptive load prediction and machine learning with thermal image processing to facilitate the maintenance of super voltage power equipment on a real-time basis [17]-[19]. Also, it has been shown that the use of artificial intelligence models including Convolutional Neural Networks and InceptionV3 can enhance the accuracy and speed of the thermal image analysis which is required for the fault diagnosis of our equipment [20]. There has been several researches in the recent past on the application of IRT for motors and substations monitoring, analyzing the performance of these equipment ensuring better robustness and integrity [21]-[23].

Also, the stereo camera aided vision together with thermal imagery has enabled a new vista in the inspection of power lines by micro aerial vehicles [24]. On the other hand, regression based and deep learning based approaches have also been successful in sharpening the performance of the imageology of thermal images.Images aimed at the analysis of faults in electrical assets.

2.1 Methodology

To improve IR image recognition, the image is collected from a specifically prepared black screen environment. Colored filters are semi transparent color sheets that are used to filter out frequencies. The lens is an integral feature of the camera that allows for manual focusing. The Charge-Coupled Device (CCD) matrix is the camera's transducer, which translates the image to appropriate voltage levels. The electronic driving mechanism is a CCD Matrix USB converter.

A CCD [25] is a device that allows electrical charge to be moved from within the device to a location where it can be handled, such as conversion into a digital value. This is accomplished by sequentially "shifting" the signals between stages within the device. Charge is shifted between capacitive bins in CCDs, with the shift allowing charge to be transferred between bins.

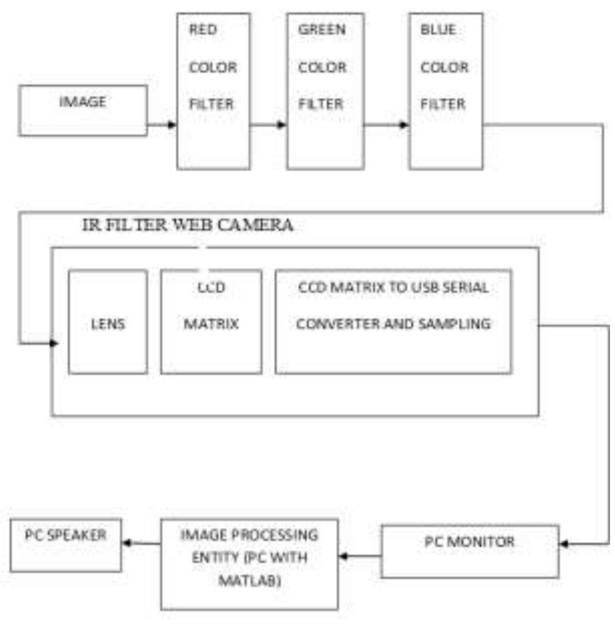

Fig.1. Block Diagram of Hot Spot Detection System

Image processing applications are run on a computing device like Personal Computer (PC) using Mat lab/Sci lab. PC Speakers and monitors are used in our design as audio visual interfaces.

2.2 Experimental Procedure

Experiments were conducted to assess the performance of a Webcam based security camera for thermal imaging. The camera used was based on the I ball 20.0HD Web camera module, which has a light sensitivity down to 0.01 lux. The camera output was connected to a digital frame store resident in a personal computer. The frame store digitizes the camera signal as a 512 by 512-pixel image; each pixel is digitized to one of 256 intensity levels (i.e., 8 bit) where 0 represents minimum or no intensity (black) and 255 represents maximum intensity (white).

All the experiments were carried out in a closed environment. A soldering iron serves as the temperature reference for the test. Make use of a multimeter temperature probe for regression training temperature measurement, and successfully read the image and interface it to the PC using PC software MATLAB. The average of R, G, and B values was calculated using image processing, and the reading was taken and tabulated for various temperature ranges. Objects imaged at high temperatures - greater than 300°C - were clearly visible to the camera without any further processing, as shown in the diagram below. The level of infrared radiation from the heated objects, on the other hand, decreased as the temperature was reduced, until the heated objects were indistinguishable from noise.

3. ALGORITHMS

a) REAL-TIME PREDICTION ALGORITHM

For live prediction, trained polynomial coefficients are used. The precision is determined by the number of samples used and the regression algorithm used.

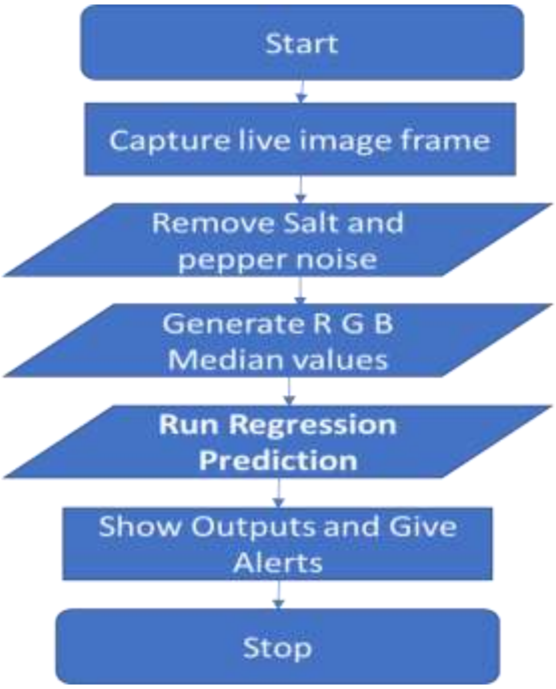

Fig.2. Prediction Algorithm

b) TRAINING ALGORITHM

Prior to using the online temperature prediction, training is needed. The training mechanism generates the coefficient of the equation.

Table 1 illustrates the various temperatures and their respective RGB values.

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4. RESULTS AND OBSERVATIONS

To enable testing, a closed optically insulated environment was established. A soldering iron serves as the temperature reference for the test. Use a multimeter temperaturse probe to measure the temperature during regression training. MATLAB was used to successfully read the image and interface it to the PC and estimate the average of R, G, and B values using image processing. By getting the temperature readings and tabulating them for different temperature ranges.

Table 1: R, G, B Values at different temperatures.

TEMPERATURE (°C)	RED	GREEN	BLUE
29	38.56	36.8	39.75
33	39.765	38.034	39.6743
38	42.759	37.985	43.1264
39	43.337	40.556	44.1277
44	60.509	50.823	57.786
50	62.32	51.7	59.53
64	64.79	51.04	56.79
126	66.3575	53.122	65.874
137	74.31	55.7	66.76
140	74.51	63.587	73.167
145	57.93	50.34	56.27
153	110.13	72.48	87.29
155	60.5	50.82	57.782
178	62.44	52.71	60.03
190	61.28	49.02	58.53
195	54.86	46.23	52.01
220	57.964	48.643	58.35
239	111.3811	74.698	88.591
256	82.18	66.412	72.47
270	79.93	67.4017	76.022
290	70.365	54.617	66.629
307	70.59	59.76	69.635
313	74.27	62.989	71.873

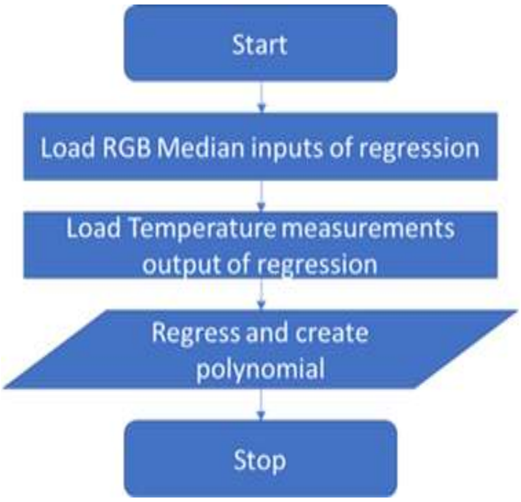

Fig.3. Training Algorithm

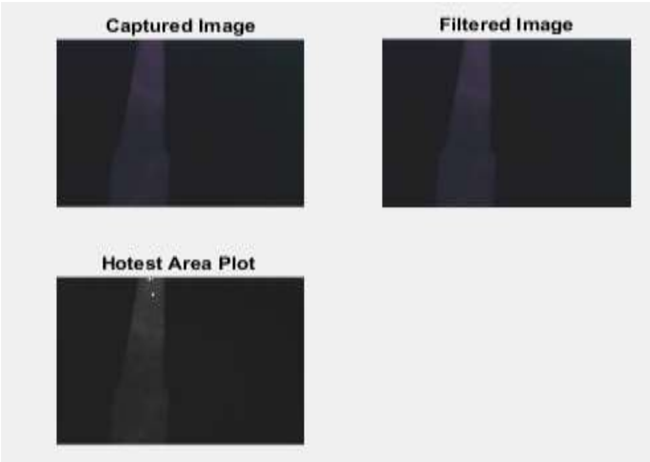

Fig.4. Images of soldering iron at 163.07°c

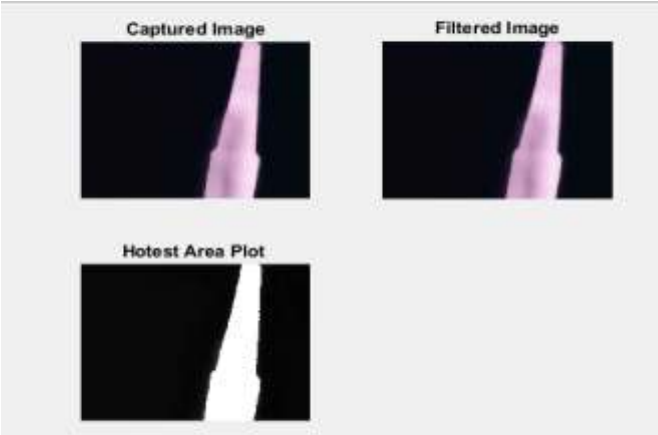

Fig.5. Images of soldering iron at 207.95°c

5. CONCLUSION

Our Condition monitoring has grown in importance in the field of electrical equipment maintenance, attracting increasing attention around the world. The prospective functions of failure prediction, defection detection, and life estimation provide utility firms with a number of benefits, including lower maintenance costs, longer equipment life, improved operator safety, reduced accidents and the degree of destruction, and improved power quality.

The experiment culminates in a successful implementation. It's a physically testable piece of hardware that works on artificial intelligence regression topology. On this specific implementation, multivariable linear regression performs admirably. The problem persists because of the low temperature zone, on which we are not concentrating as much. However, the device appears to be performing properly in your area of interest.

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